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The Built Environment Yorkshire Health (BEYH) Study: a protocol for a multi-level cross-sectional study

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Abstract

The Built Environment Yorkshire Health (BEYH) study will be a multi-level cross-sectional study that examines associations between the built environment (both physical activity and nutritional) and body weight in n=27,806 adults. Measures of the built physical activity and nutritional environment will be objectively measured using Geographic Information Systems (GIS). Multi-level models will explore how both individual- and neighbourhood-level factors contribute to body weight. Original aspects of this study include the exploration of the mediating effects of both individual and area-level socio-economic status and interaction effects between the food and physical activity built environment. Following completion of the project results will be offered to key stakeholders such as local authorities. Research findings will be disseminated to the scientific community in the form of conference presentations and peer reviewed journals.

Keywords

Obesogenic environment, obesity, physical activity, nutrition, built environment

1.0 Introduction

The positive benefits of maintaining a healthy body weight are well documented [1,2,3]. Unhealthy body weight is associated with an increased risk of diabetes, cardiovascular disease and some cancers [4,5,6]. Furthermore, obesity related illnesses are estimated to cost the NHS £5.1 billion per year [7]. Increased body weight continues to be one of the leading burdens of disease in the UK [8]. Despite this, obesity rates in the UK continue to be the some of the highest in Europe with 24% and 25% of males and females reported to be obese respectively [9].

Governments and local authorities have repeatedly attempted to address the issue of rising obesity levels however, their approaches on the whole have been ineffective with obesity trends continuing to rise [10,11]. Subsequent interventions or behavioural modification programs have only achieved limited short term success in weight loss [12]. Obesity remains a complex problem that requires action from individuals and society across multiple sectors [1]. To achieve sustainable long term changes it is important to understand how behaviours occur within a broader ecological framework [13].

The obesogenic environment represents features of an individual's locale that encourage behaviours associated with increased body weight including an overconsumption of energy-dense, nutrient poor foods at the expense of minimal energy [14,15]. Policy makers are engaging with the idea that the obesogenic environment may be a contributing factor to the obesity epidemic. Recent attention has focused on possible actions to modify the obesogenic environment; in particular the food environment. One element of this is addressing the prevalence of fast food outlets in specific neighbourhoods to support healthier lifestyles [16,17,18].

Research has focused on the links between the food environment and obesity [15,19,20]. Studies have found positive associations between food outlet density and obesity [15,21], whilst others have reported little or no effect [16,22] and some even an inverse relationship [23,24]. Similar equivocal findings exist for the physical activity environment [25,26,27]. However, a longitudinal study recently demonstrated that living far from usable green areas or waterfront in urban areas increases the risk of overweight [28]. The contrasting evidence base is a direct result of the wide ranging complex methods used to define exposure and represent the association with the built environment [29,30]. The lack of coherent evidence has seen appeals against fast food outlet restrictions in the UK won based on planning regulations as opposed to public health arguments [17].

Some of the strongest evidence for environmental disparities in obesity patterns are associated with unequal access to food outlets and physical activity facilities [31]. A recent review of reviews highlighted that residents of low socio-economic status or ethnic minority neighbourhoods outside the US have disproportionately greater access to fast-food outlets [32]. This relationship is less consistent across other types of food stores and physical activity facilities outside of the US-centric evidence base. Notably, populations are usually treated as a whole and potential moderators such as gender are rarely explored [25]. Likewise,

mediators are rarely explored to examine the mechanisms through which the built environment may influence obesity [25,33].

It seems that despite increasing policy focus, identifying the associations between exposure to the obesogenic environment and increased body weight has proved challenging [25,34,35]. The concept of an obesogenic environment may seem intuitively appealing, yet operationally it continues to be challenging [36]. Few studies have data on both the food and physical activity neighbourhood exposures required for powerful examinations of the obesogenic environment [21]. There is little understanding as to which neighbourhood environment is comparatively stronger in predicting obesity and how different elements may interact [21]. Furthermore, the majority of the literature is derived from small study populations focusing on one aspect of the food environment or physical activity environment i.e. solely fast-food. Considering this, current evidence is not best placed to support governmental interventions into the modification of obesogenic environments [15,16].

The Built Environment Yorkshire Health (BEYH) study forms the platform to be one of the largest UK based studies examining the impact of the built environment on body weight. We will seek to add evidence to the relationship between body weight and built environment. A novel aspect will be our analysis to investigate whether exposure to the food or physical activity environment has mediating effects on the association between body weight and socio-economic status (measured at both the individual- and area-levels). Furthermore, we will also investigate the interaction between the food environment and physical activity exposures to build on prior research that considers them in isolation, despite operating in the same environment.

The BEYH study will include a range of exposures to represent the nutritional and physical activity environment to rigorously test their associations independent of how the obesogenic environment is measured. A similar approach will also be taken with the measures of body weight. The aim is to better respond to the urgent need to identify more rigorous evidence based policy to tackle the obesity epidemic [1,37] and guide policy change and the redesign of key existing urban environments. This will maximise physical activity, adequate nutrition and reduce obesity, all key determinants of human health and quality of life [13,38].

This study will provide a high-quality basis from which to assess the relationship between the obesogenic environment and body weight across Yorkshire, more specifically research questions include:

- What are the mediation effects of individual and area-level socioeconomic status?
- What are the interaction effects between the nutritional and physical activity environment?
- What effect does the obesogenic environment have on an individual's self-reported body weight?
- Is there a spatial or demographic patterning of the obesogenic environment?
- How does the distribution of the obesogenic environment vary across the study area?

2.0 Methods and analysis

The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) recommendations will be used to ensure a coherent and meticulous set of methods and analyses, something that most current observational studies exploring this topic fail to incorporate [39].

2.1 Study Design

The BEYH will be a cross-sectional study that examines associations between the built environment (both physical activity and nutritional) and body weight in $n=27,806$ adults. Associations between the obesogenic environment and body weight will be represented by body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WhtR). Furthermore, a novel outcome measure will combine BMI and WC to provide a risk of disease index [40].

2.2 Data sources

The UK has a world-leading infrastructure for social and economic research capable of high-impact policy relevant research using pre-existing data. However, these powerful secondary data sources are rarely exploited to address some of the most pressing challenges facing modern society [41]. Consequently, the UK Ordnance Survey Points of Interest (PoI) database will be combined with individual level data obtained through collaboration with The Yorkshire Health Study (formerly the South Yorkshire Cohort Study) which offers a large range of self-reported health-related information on a representative population [42]. The Yorkshire Health Study uses a two stage sampling strategy for initial data collection. Firstly, general practitioner (GP) surgeries were contacted with a view to participating in the study (43 agreed, 50% acceptance). Consenting GP surgeries then mailed letters of invitation to all patients between 16 and 85 years of age. Included with the letter of invitation was an eight page questionnaire for data collection. Of the 156, 866 questionnaires issued, 27, 806 were returned (response rate; 15.9%).

Uniquely this data will then be joined with exposure variables of the built environment computed in ArcGIS (*version 10.2.2, ESRI Inc., Redlands, CA*) using the PoI database [43]. The PoI dataset contains the location of all commercial facilities across England. Concerns have been raised around the accuracy of this type of facility dataset [44]. However, recent work has gone some way to validating the PoI database against the arguably more comprehensive listings held by Local Government. PoI provided a viable alternative to other such data sources [30]. Measures of green, blue and domestic garden space will be obtained from the Generalised Land Use Database [45]. Original measures of park quality will be collected through observation using the physical activity resource assessment tool (PARA) [46].

2.3 Setting

Data from wave one of the YHS and the PoI database from the Ordnance Survey will be requested for the county of Yorkshire and The Humber, England. The region consists of 21 metropolitan boroughs, unitary authorities or local authority districts containing a population of 5.28 million people. The median age for the region was 39 with 89% of the population

declaring their ethnicity as white. Previous research highlights that obesity levels in the Yorkshire and Humber region are on the whole worse off than the national average [47].

2.4 Exposure, Outcome and Covariate Variables

2.4.1 Exposure Variables

A variety of exposure variables will be calculated around the individual's home postcode (Table 1). This will allow consideration of the impact of choosing different variables on results. Participant's homes will be geocoded by postcode. Food outlets will be categorised into three groups of supermarkets, takeaways and other retail. Physical activity facilities will be included as a single category initially (other classifications will be explored in future studies).

The quantity of green, blue and domestic garden space will be represented by the Generalised Land Use Database (GLUD) for the Lower Super Output Area (LSOA) and Middle Super Output Area (MSOA) the individual lives in [45]. Briefly, the LSOA and MSA are UK Census geographies designed for small-area statistical analysis. A LSOA has a minimum of 1,000 and a maximum of 3,000 people. A MSA has a minimum of 5,000 and a maximum of 15,000 people [48]. The locations of parks obtained from Open Street Map will be assessed for quality by the Physical Activity Resource Assessment (PARA) Tool [46].

Table 1 A summary of exposure metrics used to represent the obesogenic environment

Availability	Accessibility
Counts by administrative area	Straight line distance to nearest PoI
Density by administrative area per population	Street network distance to nearest PoI
Density by administrative area per ha	Straight line distance to nearest 20 PoI
Density per administrative area by population accounting for extra-local effects	
Density per admin area by km ² accounting for extra-local effects	
Count within post code based centroids using circular buffers of 100m, 400m, 800m, 1000m, 1600m and 2000m.	
Count within post-code based centroids using street network buffers of 100m, 400m, 800m, 1000m, 1600m and 2000m.	

Note: Administrative areas will be defined as LSOA and MSA unless stated otherwise

2.4.2 Outcomes Variables

Body mass index (BMI)

Weight (kg) and height will be reported by participants. BMI is calculated as weight (kg) divided by height (m) squared. Participants will then be split into categories of underweight (BMI<18.50), normal weight (BMI 18.50 – 24.99), overweight (BMI 25.00 – 29.99), obese I (BMI ≥ 30.00-34.99), obese II (BMI ≥ 35.00-39.99) and obese III (BMI ≥ 40.00). Two binary variables of i) overweight and obese or not and ii) obese or not, will be also be created.

Waist Circumference (WC)

The waist circumference (cm) of each participant will also be reported. For males, a waist circumference of less than 94cm is low, 94-102cm is high and more than 102cm is a very high risk of developing additional health risks associated with overweight and obesity. For females a waist circumference of less than 80cm is low, 80-88cm is high and more than 88cm is very high [40]. Two binary variables of i) increased risk or not and ii) substantial increase in risk or not were also defined.

Index of Disease Risk

As shown in Table 2 The National Institute of Clinical Excellence [40] suggests the assessment of health risks associated with overweight and obesity in adults should be based on BMI and WC to determine if the adult is at any increased risk of associated health threats.

Table 2. Assessment of health risks associated with adult overweight and obesity based on BMI and waist circumference

BMI classification	Waist Circumference		
	Low	High	Very High
Overweight	No increased risk	Increased risk	High risk
Obese	Increased risk	High risk	Very high risk

For men, waist circumference of less than 94 cm is low, 94–102 cm is high and more than 102 cm is very high.
For women, waist circumference of less than 80 cm is low, 80–88 cm is high and more than 88 cm is very high.

Waist-to-height ratio (WHtR)

Waist-to-height ratio will be calculated as WC (cm) divided by height (cm). Subsequently, adults will be classified as at risk of health implications if their WHtR exceeds 0.5 i.e. WC is more than half their height.

2.4.3 Explanatory factors

Age, gender, ethnicity and individual level socio-economic status will be included in analyses (Table 3). The area level measure of socio-economic status used is the Indices of Multiple Deprivation 2010 [49]. A rural or urban classification (in line with local government definitions) will also be included for consideration in statistical analyses [50].

Table 3 Summary of study exposure, outcomes and covariates

Exposure	Covariate
<i>Exposure</i>	Demographics
Food outlets	Age
Physical activity facilities	Gender
Green Space	Ethnicity
Park location	Individual level socio-economic status
Park size	Education
Park quality	Employment status
Blue Space	Occupation
Domestic Garden Space	Area level socio-economic status
Crime levels	Index of Multiple Deprivation (IMD)
<i>Outcomes</i>	Rural/urban classification

Body weight	Rural/urban typologies
Body Mass Index (BMI)	
Waist Circumference (WC)	
Waist-height-ratio (WHtR)	
Index of disease risk (BMI + WC)	
Physical activity behaviour	
Physical Exercise	
Cycling	
Walking	

2.5 Bias and missing individual level data

Rigorous data validity checks will be in place by all parties involved (Yorkshire Health Study, Ordnance Survey and Author). Missing data will be flagged for checking and explored whilst duplicate case analysis will be completed. Subsequent steps to deal with the missing data will depend on the type (missing completely at random, missing at random and non-ignorable missing data), amount and distribution of missing data [51]. Ideally, data will be included only if postcode, gender, age, ethnicity and both BMI and WC are present, if age is greater than 18 years of age and the postcode lies within Yorkshire.

2.8 Statistical methods of analyses

The proposed dataset has a hierarchical structure consisting of adults nested within neighbourhoods. To account for this structure, we will use a multi-level modelling (MLM) framework to analyse the data. Linear MLM's (random slopes) will explore how both individual- and neighbourhood-level factors contribute to BMI. Predictors (Table 3) will be sequentially added to models and possible interactions between explanatory variables will be explored. Additional binary logistic and linear MLM's will then be built for all body size outcomes outlined previously (BMI, WC, WHtR, BMI & WC combined). Furthermore, analyses will be extended to test for mediating effects of the obesogenic environment on the explanatory variables (e.g. deprivation). Originally, the differential effect of area-level deprivation on body-weight for people with different levels of education a cross-level interaction will be included as a fixed effects parameter as consistent with previous research [52]. The differential effects will then be visualised using interaction plots. The other confounders will be included as fixed effects to control for and estimate their relationships.

3.0 Ethics and dissemination

Ethical approval for the YHS was granted from the Leeds East NHS Research Ethics Committee on 22 April 2010 (ref: 09/H1306/97) and the relevant Local Research Ethics Committee. Data from both the YHS and Ordnance Survey will be stored on a secure password protected computer that only the named researchers will have access to. All YHS data will be anonymised at the individual level. Following completion of the project results will be offered to key stakeholders such as local authorities and reported back to collaborative organisations such as the Yorkshire Health Study Management Group. Research findings will be disseminated to the scientific community in the form of conference presentations and peer reviewed journals. Further, government organisations, health boards and councils will be able

to access key findings and recommendations resulting from the project through seminar presentations and report distributions.

4.0 Discussion

The study protocol for the BEYH study which seeks to examine the associations between objective measures of the built environment and body weight in a large scale multi-level cross sectional study has been outlined. Original aspects of this study include the exploration of the mediating effects of both individual and area-level socio-economic status and interaction effects between the food and physical activity built environment. Furthermore, objective exposure variables will go beyond previous research; for instance by including not only green space but the location and quality of parks as exposure to the physical activity environment. This study will also use a range of rigorous and original outcome measures. For example, utilising recent NICE guidance [40] will provide local authorities with contemporary evidence at a time when they are considering substantial reform and planning restrictions in the built environment [17,18].

Despite consideration of planning restrictions, findings outside the US-centric evidence base remain inconsistent [32]. The relationship between the availability of different types of food outlets and body weight remains contested [32,53]. There has been less consideration of the role of physical activity facilities, as well as the exploration of the availability of green, blue space, parks and the quality of park provision in relation to body weight [54]. Whilst some of this evidence shows an important role for the built environment the use of differing methods, limited variance of environmental variables and small sample sizes may serve to underestimate the observation observed. Current evidence also tends to focus on a single risk factor, and ignores how these contributing factors co-exist. We will seek to build upon this evidence base and address current issues with research.

Relationships between body weight and the built environment may be further complicated by interacting, moderating or mediating effects. However, these associations are rarely explored in more complex conceptual or statistical models [25]. For example, we hypothesise that the physical activity environment (i.e. the availability of green space) may interact with or affect the relationship between fast-food outlet availability and body weight. Furthermore, associations may also change by other factors such as gender, ethnicity and socio-economic status but these associations are rarely explored or reported. Given the complexity inherent in the built environment, understanding its influence on obesity requires more complex multilevel models that explore the impact of, interacting, mediating or moderating factors.

There are several limitations to our study. Firstly, data are cross-sectional in design which limits our ability to draw causal interpretations. Secondly, data from the YHS are self-reported and therefore subject to bias. For example, height has been shown to be overestimated, with weight under-estimated and these biases may underestimate BMI [55]. Furthermore, as with many other studies the actual location of food consumption or physical activity is not known. Nonetheless, the limitations of arbitrary neighbourhood definitions are not unique to this study and debates around accurately defining ‘neighbourhood’ continue

within the literature [56,57,58]. Few studies have considered the impact of different sized neighbourhoods on results [59,60]. Finally, to inform local level policy the classification of food outlets was based on local authority databases. This simple stratification, of food outlets in particular may be a further contributing factor to the equivocal evidence base [61,62].

Our study responds to the need to exploit powerful databases to better inform evidence based local policy [41]. The BEYH study will form one of the largest and arguably most rigorous studies to date with various original and objective measures of both the physical activity and nutrition environment. Furthermore, body weight will be represented by not only BMI but waist circumference, waist to height ratio and index of disease risk all of which offer different markers of overall health and disease risk [63]. Moreover, we will investigate the interaction between the food environment and physical activity exposures to build on prior research that considers them in isolation, despite operating in the same environment. Finally, original mediation analyses will explore differences between individual and area-level socioeconomic status; extending much previous literature and progressing the evidence base [25].

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